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Scientific Sense-Making in Elementary Classroom Conversations

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ABSTRACT

This work examines the conditions for the development of scientific sense-making in fifth and sixth grade classroom science lessons. Scientific sense-making is a process in which theory and evidence are brought into coordination. Classroom activities that were structured as a series of presentations are compared to activities structured more as conversations with respect to their consistency with, and support of sense-making. Features of conversation such as displaying the relevance of one turn to the previous turn are shown to support the movement of ideas during the activity and to display important elements of sense-making. A close relation between conversation and sense-making is proposed.

Our goal in the work reported here is to understand the conditions which help students learn to theorize scientifically. We examined a number of sixth grade lessons concerned with seasonal change, searching for evidence that young students elaborate and critique theories in a manner resembling scientific ways of making sense. Scientific sense-making is a process in which theory and evidence are brought into coordination. It is a dynamic process in which there is a movement and development of ideas as new evidence is introduced and as theoretical concepts are refined and changed. We have begun defining what we now call sense-making conversations as a basis for our conjecture that children will develop sense-making as a skill to the extent that they are able to engage in sense-making conversations.

Our observations focus on the conditions under which we find a movement and development of ideas. We assume that such movement is a central feature of the sense-making process and an important indicator that sense-making is going on. We suggest that "show and tell" presentations, a common non-conversational way of organizing classroom science discourse, can work against scientific sense-making. However, when students address one another, spontaneously offer to speak, refer to previous comments, take up old arguments, or ask questions, we instead see movement of ideas. Students change their opinions and elaborate ideas. This movement of ideas, which was not observed in the show and tell presentations, provide us with an initial indication that cooperative conversation is an important condition for the development of scientific sense-making in the classroom.

What is Scientific Sense-making?

Several popular accounts of scientific practice have clarified the political and social dimensions of science. Watson's (1969) story of the discovery of the structure of DNA is filled with accounts of the rivalry between laboratories, accounts which are at odds with the "textbook" version of scientific method, in which hypotheses are neatly generated, tested, and either rejected or confirmed. Latour's (1987) description of science in action likewise contrasts the messy production of scientific data in real laboratories with the tidy product that appears in textbooks. Kuhn's (1989) account of paradigm shifts highlights the importance of creative leaps of imagination, bringing into question the popular view of scientific progress as methodical and incremental.

Given these accounts of the actual practice of science, what can we make of the appeals of reformers for an education in science that gives students hands-on experience with real scientific investigations? These reforms will have to be guided by an idealization of the scientific process, an idealization that captures the essence of what science *should* be, that distinguishes it from other disciplines, and that suggests ways of doing real science in a school context. As a starting place for our research, we assume that an important goal of science education must be to provide opportunities for students to engage in *sense-making*, a collaborative enterprise characterized—not by the systematic application of scientific methods—but by an on-going struggle for understanding.

Following Medawar (1987) and D. Kuhn (1989), we see sense-making as the attempt to coordinate models (theories, explanations, etc.) with data (evidence, observations, "facts," etc.). The goal is a supportable answer to the question that accounts for (or models) the observed pattern. Coordination goes both ways: data may be collected as a basis for a model but the developing model guides

data collection and predicts new data in a continuous cycle. Although our focus is on sense-making in science, we recognize that the ability to do meaningful work in the medium of theory and evidence is demanded in most (if not all) disciplines and careers—is in fact an important life skill for citizenship in a democratic, technological society. A theory in science may be a diagnosis in medicine, a case in law, a plan in business, a design in architecture, or a policy initiative in government.

As in other disciplines, model building and data collection in science are sometimes separate activities. For example, Watson and Crick devoted much of their efforts to the job of developing a concrete model of the molecule, while Franklin concentrated on collecting the X-ray crystallography data that would constrain the model. Although these functions were distributed socially, and although rivalry was a salient part of the discovery of DNA's structure, the theory and the evidence were ultimately coordinated in one integrated enterprise. The coordination of theory and evidence was a collaborative accomplishment in which the scientific community as a whole, through a kind of conversation, came to a new understanding about DNA. The coordination of theory and evidence encompasses a wide variety of activities including data collection, calibration of instruments, and construction of computer models which derive their meaning as part of the sense-making enterprise.

Learning to Make Sense Scientifically

We assume that the ability to maintain a working distinction between theory and evidence is culturally acquired—it does not come "naturally." It is a peculiar way of acting that is culturally defined and develops as a result of specific scientific schooling. In saying this we do not imply that people without scientific

schooling have no ways of making sense of the world or that scientists have only one way of making sense of the world. We are careful to distinguish scientific sense-making from the much more general notions of making sense. We are concerned only with the origins of scientific thinking.

We recognize that there are, of course, many reasonable ways of making sense found commonly among children as well as adults that are nevertheless non-scientific. For example, Rosebery et al. (1992) report the following conversation between an interviewer and student about the effects of water pollution in Boston Harbor. The conversation was conducted prior to an intervention aimed at improving scientific reasoning.

Interviewer: What do you think might have made the fish die?

Tony: Because the garbage is a poison for them.

Interviewer: How would you know it was the garbage that was making the foam and the fish die?

Tony: The garbage made the fish die.

Interviewer: How would you make sure?

Tony: Because fish don't eat garbage. They eat plants under the water.

Although the student clearly has a reasonable causal model in mind (the pollution caused the death of the fish), he responds to the interviewer's initial request for evidence (How would you know...?) with a simple restatement of the theory. In response to the second request for evidence (How would you make sure?), he provides a sort of corollary to the theory (garbage is not the natural food of fish). It seems clear that the student is not distinguishing between his

theory about what killed the fish, and evidence that might be gathered to support or disprove it. Rather, theory and evidence are joined in a single representation of what Kuhn calls the "way things are" (Kuhn, 1989).

With examples such as these in mind, we follow Kuhn and her colleagues in positing two characteristic ways of explaining phenomena. The first, a "way-things- are" view of the world, makes no particular distinction between facts and the explanations that account for them. Both theory and evidence are melded into a single undifferentiated construct. The understanding of the phenomena may include causal connections or other mechanisms that, informally, could be called a theory of the phenomena. However, the "way-things-are" world view critically fails to distinguish these theory-like explanations from evidence which could support them. Not being true theories, grounded in evidence, these pseudo-theories lack the hypothetical qualities which allow thinkers to mentally manipulate variables (positing "if we changed this, then that would follow") or revise theories when counter evidence presents itself. Observed phenomena and their causes are simply the way things really are.

The second view, the more "scientific one," clearly distinguishes between theory and evidence. Theories try to account for evidence, and evidence can be used to support or refute a particular theory. Theories are inherently tentative, being subject to revision in the face of new evidence.

In Figure 1 we have used the terms model and data instead of theory and evidence. Model and data refer more concretely to the artifacts we observed in use in our classroom discussions of seasonal change where globes and balls and lights were used as solar system models and readings of shadow length or day length were the data they collected. The figure captures the essential

differentiation of the understanding of phenomena characteristic of scientific work.

Insert Figure 1 about here.

Once theories and evidence are differentiated, it is possible to treat the model as hypothetical. The model tries to account for the data, and data can be used to support or refute a particular model. Both the model and the data are understood as artifacts independent of the phenomena itself. Theories are inherently tentative, being subject to revision in the face of new evidence, and so on.

We treat the differentiation of theory and evidence not so much as a cognitive stage of development but as a social construct that arises in contexts (laboratories, classrooms, or other work settings) that are organized for scientific work. This view follows from a general approach to cognitive change described by Newman, Griffin and Cole (1989) in which constructive processes are observed in social interactions and is consistent with the concept of learning as participation proposed by Lave and Wenger (1991). Building on the work of Vygotsky and others in the socio-cultural school (Rogoff, 1990), this paradigm moves away from examining just the continuous development within the mind of the child and examines the construction that occurs in interaction with parents, teachers, and others as a source for new concepts and skills.

From this perspective, therefore, we are particularly concerned with the relationship between classroom language activities and the opportunity for scientific discourse to arise, that is, discourse that displays a differentiation between the model and the data. We focus specifically on interactions within two classroom language activities—*presentations* and *conversations*. Given our view of scientific sense-making, how can we begin to suggest ways to organize classroom discourse?

Language Activity and Scientific Sense-making

In this section, we develop the distinction between two language activities that we observed in our classrooms. The matrix shown in Table 1 provides examples of four kinds of language events. The two axes, language activity and epistemology, are independent in the simple sense that we have no difficulty filling-in typical examples of each cell. The matrix will allow us to frame our initial questions once we present in more detail the distinction between presentation and conversation. Our concern is that presentations and conversations are not equally amenable to constructing the differentiation between theory and evidence that is essential to a scientific epistemology.

Insert Table 1 about here.

Presentations and conversations are not the only language activities to be found in classrooms. In fact, conversations are relatively uncommon and both forms are less common than the pervasive teacher talk that has been extensively documented in other work (Mehan, 1979; Cazden, 1988). But we find that

presentations are a well practiced form and one that teachers will commonly draw upon as they move toward engaging students more actively in scientific work.

Presentations as an Outgrowth of 'Sharing Time'

We view presentations as language activities in which participants take turns telling stories or sharing their ideas formally. They are shaped by a characteristic lack of the Gricean (1975) requirement that turns be relevant to preceding or following turns. As participants take turns, there is no obligation to refer back to what previous presenters may have said, nor is there any particular obligation to respond to objections made by others, should these be raised. Themes may or may not be shared across turns. The presentation format honors equity in speaking time—everyone should be given a chance to speak for roughly equivalent periods of time. Presentations are common in many classrooms. "Sharing Time," or "Show and Tell" is practiced in its purest form in the early grades, reappearing with variations throughout school. Presentations in the form of oral science reports, group project reports, or individual presentations of personal 'theories' were common in the data we will present.

In the midst of a sequence of individual student presentations on the causes of seasons, one teacher made his intended 'sharing' format explicit. While encouraging a student who seemed reluctant to make her required contribution, he explained:

Teacher: Shhh. For a lot of people it's a little bit scary coming up. And I understand that. But, in all of your classes you, you're always asked to come up to demonstrate, to read something, to show something, you did

> show and tell as a little kid in nursery—I mean kindergarten and first grade, right? Show and tell. It was just as scary as this wasn't it? At the time that you did that.

With this one statement, the teacher placed his current classroom activity squarely within the tradition of 'sharing time' presentations. Another teacher voiced the expectation that presentations be "ready," that is, practiced, fluent, and "without all this stopping and thinking." In other words, there was no room for *revision*, and real-time sense-making was not supported.

Conversations

Unlike presentations, conversations assume relevance across turns as participants cooperate to build a shared perspective through language. Although we recognize the value of "real discussion" among equals (Cazden, 1988), or *cross-discussion*, to use Lemke's term (1990), we do not limit our definition of conversation to this form since we wish also to include conversations between teacher and student and among students with different epistemologies. We also find elements of conversation interspersed in other kinds of language activities. We identified the following features which preserve conversational relevance as key to the definition of conversation used in the analysis of our data:

1. *establish given and contribute clearly marked new information.*

2. *select turns locally through self-selection or speaker selection* (Sacks, Schegloff & Jefferson, 1974).

3. *contribute comments or ask questions at the time that they naturally arise* (see Grice's *Cooperative Principle*, 1975).

4. *respond to a challenge or question.*

These features, as elaborated below, form the basis for our subsequent analysis.

Given/new. Given information is established by referring to previous discourse, citing others, agreeing with others, or summarizing previous discourse. This process sets new information apart, bracketing it within the context of previous discourse. Now speakers have a basis for comparing how their ideas coincide with or differ from that which has gone before. The new information acquires *relevance*. When speakers present new information without connection to old, it remains an odd collection of assorted pieces. Speakers who merely repeat the given as if it were new show a disregard for relevance. Their turn marches in place, failing to move the conversation forward toward a mutual goal.

Turn selection. Turn selection can either be controlled locally in the conversation or by some pre-established set of rules. Sacks, Schegloff and Jefferson (1974) note that, when a speaker bids for a turn or chooses the next speaker, he or she exercises local control of turns, thus maximizing the chance that turns will be relevant. In contrast, when turns are decided in advance, fit into presentation slots, or are determined by the teacher, relevance may be sacrificed. Potential speakers may stop bidding for a turn when they perceive that their comments have become stale. Alternatively, when the comment is finally aired, it no longer fits into the conversation. Sacks et al. (1974) also note that local turn selection allows the number of potential participants to vary, each participant has the potential to become the next speaker. But as participant numbers grow, as is the case in a full-class discussion, the likelihood that speakers will get an equal chance to speak diminishes. Conversations, unlike presentations, do not *ensure* that every participant (or participant group) will get a turn.

Contributing comments and questions as they naturally arise. Conversations flow naturally when comments and questions arise in response to what others have said. Comments which triggered each speaker's thoughts are fresh in the minds of listeners rather than being ancient history. Questioners ask questions when they first become puzzled. Speakers settle differences on the spot. As speakers contribute to the conversational flow, strings of related content emerge.

Responding to challenges. Speakers violate a fundamental tenet of relevance if they allow questions to go unanswered. By asking a question, the speaker has undeniably selected the addressee as the next speaker. Answering, or explicitly declining to answer, is the only relevant response; other options produce conversational breakdowns.

When participants maintain relevance across turns, other discourse features follow naturally. The path laid down by a sequence of relevant turns lends a *dynamic* quality to the discourse that contrasts with the static quality of disjoint and isolated turns. The following characteristics contribute to dynamic interaction: 1) maximum variety of potential speakers at a given change in turns, 2) opportunity to develop themes across turns, 3) active comparison and contrasting of content, and 4) a cycle of posing, challenging, and revising ideas.

Interaction Between Epistemology and Language Activity

Returning to the matrix of epistemologies and language activities, we can consider possible interactions between the two dimensions. In particular, might differences along the language activity dimension lead differentially to changes along the epistemology dimension? Given a goal of moving students toward a

differentiation of theory and evidence, might organizing classroom science discourse as presentations or as a conversation make a difference?

To address this question, we have to step back to consider what we mean by epistemology in our current work. Both the language activity and the epistemological dimensions refer to public constructions. The epistemology we are referring to is that which is displayed in publicly available performances. We are concerned with the epistemology that gets constructed among the participants because, according to the Vygotskian approach to development we are assuming, these public constructions are the drivers of cognitive change in the students (Newman, Griffin & Cole, 1989). Indeed, changes in epistemology can be understood as changes in the level of participation in scientific work and conversation.

We do not wish to make assumptions about the underlying cognitive capabilities of the participants, based on their public performance. Obviously, working scientists can carry on ordinary "way-things-are" conversations around the dinner table without our attributing to them a loss of cognitive capability. Conversely, a student may present a perfectly correct theory of seasonal change, stating it as the "way-things-are," although in other circumstances he or she might be able to debate the significance of new data, offering other hypothetical possibilities. While epistemology does not refer to an individual mental state, in many cases, we can nevertheless identify the public performance with a single actor. For example, responsibility for an individual presentation is easily attributable to that individual. An important consideration arises when the language activity is a joint activity such as a group presentation or a conversation. Here, the language activity and the epistemology displayed in it are the responsibility of a group. A debate among a group of students might

display a differentiation of theory and evidence that is difficult to attribute to any single turn.

Furthermore, the turns at talk within a language activity, especially conversation, may not display a consistent epistemology. It is quite likely that a classroom conversation will contain turns that can be characterized differently. For example, a student may make a suggestion about the way she thinks the solar system works purely from the point of view of the way things are and another student or the teacher may follow up with a critique showing why that theory does not account for some known evidence. The first turn in itself does not display a differentiation but the second turn does. This heterogeneity may be a source of strength of the conversational format over the presentation format. The presentation format may be static in that students are less likely to learn anything from participation beyond the content of the "theories" taken as the way-things-are. Even where the presentation does display, for the sophisticated listener, a differentiation of theory and evidence, in the absence of conversational give-and-take, that epistemology may be less salient. In a presentation format, where there is no such give and take, competing ways of understanding the world may continue to coexist, without movement.

In the remainder of the paper we will attempt to provide evidence that conversations (or the features of conversations that creep into a sequence of presentations) are fruitful contexts for learning to participate in scientific work.

A Formative Experiment on Curriculum Design

To examine the question of how classroom language activities might support scientific sense-making, we used data from three Boston area classrooms. One of the participating schools was a K-6 school located in Hillsborough—a homogeneous middle-class suburb of Boston. In this school, two sixth-grade teachers team-taught science and other subjects. The second school was a K-8 school in an ethnically diverse area of the city of Riverside. This alternative public school served, in particular, a large Haitian population. We worked in a combined 5th-6th grade classroom taught by a single teacher.

The three teachers volunteered to help develop and implement a 5th-6th grade curriculum unit on seasonal change. With assistance from the researchers, the teachers' task was to design a unit that would include modeling and data collection, and to attempt to integrate the use of technology into these activities. The goal of the unit was to engage students actively in classroom activities. The classrooms were also to be the site for a parallel experiment with the use of drama that was also integrated into the seasons unit.

In formative research, we support changes in the settings as a deliberate attempt to achieve a predefined goal, in this case, scientific sense-making. Both teachers and researchers collaborated in finding ways to encourage sense-making in the classroom. This is in contrast to a controlled experiment in which the outcome of controlling certain variables and varying others is hypothesized but unknown. On the other hand, our formative experiment put the researchers in a more active role than is typical of naturalistic observation. Teachers and research staff met approximately every three weeks to discuss progress and compare notes. These meetings were an opportunity for the research staff to both support the teachers as they planned next steps in the curriculum and to make suggestions concerning

the use of technology, classroom discussions of data, and so on. The researchers also conducted interviews and made observations, supported by field notes and video. The researchers themselves conducted the drama and some of the simulations activities in the classrooms.

Researchers helped the teachers develop a year-long curriculum designed to give substance to the content goals and the instructional approach, including both data collection and work with physical models. The curriculum involved a variety of activities from which we hoped students might themselves construct theoretical models of seasonal change. In contrast to the implied goal typical of textbook presentations or one-shot lessons on seasonal change, the teachers were committed to teaching the model only indirectly, expecting students to work through the problem using a variety of clues and data.

Lessons were structured to give small groups of students opportunities to examine sets of data, to theorize about them, and to present their theories to the rest of the class. In an earlier paper (Newman, Morrison & Torzs, in press) we documented a consistent pattern in the instructional approach. The teachers reported on in that paper were committed to teaching the *model* of how the seasons change, often inadvertently subverting the constructive sense-making process. In this paper we focus on the relationship between sense-making and classroom discourse patterns. We do not attempt to make any comparisons across classrooms, nor to measure cognitive change in individual students. Our design did not test the efficacy of the curriculum in any direct way.

The Content Domain: Seasonal Change

While the study of seasons is common in elementary school science, the topic is complex. But because it relates to phenomena that are part of children's everyday

experience, the topic and other topics related to the Earth and Sun, are particularly appropriate for a study of scientific sense-making at this level. A fundamental problem for scientific sense-making in this domain is part of what attracted us to it in the first place: the helio-centric model of the earth-sun relation, which is how children are taught about the seasons, is entirely counter to our geo-centric phenomenal experience. Actual data that students can collect, such as the changing elevation of the midday sun, is not easily mapped to the model so there is a built in differentiation between data and model making the analyst's task, if not the task of the students and teacher, easier. Few sixth graders have any sense of how the sun moves even during a day so there is considerable room for scientific sense-making in coordinating actual observations with a model of the rotating earth.

The key to understanding seasonal change is the fact that the earth's axis has a slight inclination from perpendicular to the plane of the orbit around the sun. As the earth revolves around the sun, this inclination results in seasonal differences in the amount of solar radiation on different parts of the earth arising from differences in the angle of the sun's rays reaching the earth and from differences in the length of the day. Very few students or adults understand this explanation even though it is commonly taught explicitly beginning in early elementary school.

Our work is not primarily concerned with describing scientific misconceptions in their various forms. We did collect, however, a rich array of student ideas about how seasons change, some of which we will review here to provide a flavor of how elementary students commonly "misunderstand" the phenomena. Far more attractive than the accepted theory, from the students' standpoint, is an explanation based on the belief that the earth is closer to the sun in the winter,

what we call the *distance theory*. We find also that young students often confuse what they are taught about the rotation of the earth as the cause of day and night and the yearly revolution around the sun and believe that the side of the earth facing the sun has summer while the other side has winter, an explanation we call the *facing theory*. A common misconception that complicates explaining the seasons is the belief that there are four seasons at any one time. The facing theory allows this since the bands of twilight are assimilated to fall and spring. Finally, we do find students asserting a *tilt theory* in which the hemisphere (northern or southern) that is tilted toward the sun is in summer. This sometimes appears as a version of the distance theory since the tilt places one hemisphere slightly (although in fact insignificantly) closer to the sun. A version in which the change results in longer days and higher angle of sun elevation in the summer is an approximation of the accepted theory. We will define other misconceptions in footnotes as they arise in our transcript excerpts.

The "theories" described above are typical of sixth graders who are remembering bits of what they have been taught about the way things are and who are including beliefs that are often incorrect, such as there being four seasons at one time or the earth being closer to the sun in summer. In general, these "theories" are not based on data that is any way distinct from their beliefs about the way things are. Most of the examples we work with in the following analysis did not begin to address the coordination of actual data and explanatory models although some of the lessons were intended by the teacher for that purpose. In what follows we examine presentations and discussions of sixth-grade theories of seasonal change.

Classroom Presentations and Conversations

In this section, we examine four lessons observed in the Boston-area schools. We begin with examples of presentations and conversations in their more-or-less pure form and then go on to examine hybrid cases, i.e., lessons in which presentation and conversation are mixed to some extent. Our goal is to show that conversational features are more conducive to the development of scientific sense-making.

Presentations— Failure to Support Relevance.

Two of the sessions we examined consisted of a sequence of presentations. In one lesson at the Hillsborough school, the teacher specifically asked students to explain why the length of day in Boston changed over a period of several months spanning the winter solstice. Students had collected data on length of day from the local newspaper. The task as initially stated by the teacher was specifically one of demonstrating an explanatory model. Groups came up to the front of the room in turn to make their presentations and followed a format (summarize data, explain, and model) laid out by the teacher. We will use excerpts from this lesson to illustrate a pure form of the presentation format.

In the second lesson, the Riverside teacher had asked his students to present their individual statements about what makes the seasons change. In contrast to the Hillsborough presentations, in which students reported on the model prevailing in their group, these presentations were planned by the teacher to reveal what individual students were thinking. The structure of the presentations also differed. The Riverside teacher promoted more loosely organized presentations — students did not come to the front of the class but rather to a table in the middle of the room. The teacher did not explicitly structure the presentation

format, nor did he prescribe a set sequence as the Hillsborough teacher did. The teacher did expect, however, that the students present individually, that they use the globe, and that presentations should go unchallenged. Turns between presentations were clearly demarcated by a request for the next volunteer. No formal question period existed, though students did ask each other questions. Excerpts from this more loosely structured lesson provide examples of teacher/student expectations of what presentations *should* be, even if actual practice does not comply with this ideal.

Pure presentations.

The Hillsborough teacher strictly structured the six presentations in her class by giving an oral outline and prompting throughout. Her lesson seemed designed in part to teach presentation format. The teacher's instructions to the class are illustrated here from the presentation by the Coolettes:

1) Give the pattern you observed

Teacher: Now, let's have the Coolettes go next. Coolettes, your theory is going to go under Hooks', and your ***** is going to go under Hooks', don't erase theirs. **Question number one, what is the pattern that you have seen,** and girls why don't you move out of the way so the Hooks can get a chance to write down their theory.

2) Say 'why' this happens

Teacher: Now that is the pattern that you have seen. All right. Why does this–

3) Demonstrate your understanding using sun/earth props

Teacher: show and tell.

4) Demonstrate the relationship for winter, summer, spring and fall

Teacher: alrighty. **Are you ready for positioning. Same thing as the boys did before. Show me winter.** (pause during which girls demonstrate the earth/sun orientation for winter) **Show me summer. Show me winter. Show me summer. All right now spring. Now summer. Now fall. Now winter. Now spring. Now summer. Now fall. Okay, now fast. Winter. Spring. Summer. Fall. Winter. Spring. Summer. Fall. One more time. Winter. Spring. Summer. Fall.**

5) Briefly compare theories (optional)

Teacher: All right. I would like the rest of the groups that are in their seats to tell me is that theory the same theory as the Hooks? Hooks, why don't you tell me.

Hooks: no.

Teacher: no, what's different about their theory?

Hooks: the sun ********

Teacher: all right. The sun certainly is different.

6) Write your pattern on the board.

Teacher: Now, Coolettes, **I need you to write your pattern and your theory on the board.** Everybody, I'd like you to make sure that their pattern and their theory agree with what they've said and what they've showed us. Go ahead.

To this sequence, the teacher sometimes added a seventh part – a question/answer section. The teacher initiated each point in the outline with a question, creating obvious seams between the six parts of the presentations.

A strictly structured presentation format is a discourse environment that effectively restricts relevance for each of the features of conversational relevance considered here. *Given information* goes unmarked while *turn selection* is determined by the teacher, not by the students themselves. In addition, student questions or comments are often deferred until the end or suppressed as violations of the format when students attempt to contribute at natural conversational points. Finally, challenges are not raised, so failure to respond to them is not an issue.

The following details how the presentations in our data failed to support conversational relevance, drawing mainly upon examples from the "pure" presentation lesson in Hillsborough, but also including those examples from the Riverside school in which presentation rules prevailed over attempts to be conversational.

1) *Given information was unmarked.* As they presented, students did not set given information apart from new. Their summaries of day length data, which

formed the preamble for each presentation, varied little from group to group. All six groups stated some version of 'the days get shorter until the winter solstice and then start getting longer again.' Here are two versions:

> "We think that it's getting small– it's getting smaller up until the winter solstice and after the winter solstice, it starts getting longer." (the Hooks' group)

> "from *** until September– until the winter solstice, the days got shorter. And after the solstice, to today, the days get longer. Afterwards they stay the same." (the Spikes' group).

No group referred to a previous group, saying 'I agree with them' neither did they allude to a pattern of agreement among groups by saying 'we all seem to be saying similar things.' By repeating the same information from group to group, students followed the classroom expectation that given information must not be omitted. The structure of these presentations created an artificial situation in which no information was treated as 'given.' New information went unmarked, and therefore unhighlighted. With new information obscured, fewer hooks existed to initiate and support the dynamic process of comparing and contrasting content.

2) *Turn selection imposed from outside.* The presentation format creates preordained slots into which individual groups insert a practiced language activity. In the Hillsborough class, the teacher assigned one group to go last based on classroom logistics, since they had a task they needed to perform which would take them out of the room. As each of the other slots became available, she asked groups to volunteer. The groups selected their slots based on their feeling of readiness rather than any perceived relevance to a previous group's

presentation. The equal opportunity each group had to address the five parts appeared to inhibit interruptions and limit cross-discussion. There was little time for across presentations, given the need to move to the next portion of the format within the time constraints that often accompany presentation format.

A major rationale for the presentation format is that everybody does get an equal chance to present. On the other hand, all students are required to take a turn, even if they don't want to or have nothing new to contribute. In the Riverside lesson, which served as an assessment of individual performances, some students were very reluctant to participate. In the following example, Tanya is called upon and painfully does her best to mimic what seems to be an accepted presentation of seasonal change. After much hesitation:

Tanya: mmm . . , mmm, I agree with uhm Cari. [Carielle]

Teacher: and wha --, can you show me how you agree with Cari ** <? and why?>

Just saying you agree isn't enough. You have to show me.

Tanya: (2 second pause) [drums fingers for 5sec].

Teacher: Tanya?

Tanya: yea?

Teacher: Can you show me-- take the globe and show me.

Tanya: [slaps table with hand]

Elsa: (sing-song) here's the glo:be. [passes globe to Tanya across the table]

Teacher: (soft) here's the globe.

Tanya: well, I think that, if it's uh winter up there, [hand on northern hemisphere]

its spring down here, [hand on southern hemisphere, then spins globe from Europe/ African conti-nent to North/South American continents]

if its summer here, and fall. [hand on N. Amer then on S. Amer]

The requirement of taking a turn for purposes of assessment may even work against assessment of a student's ability to participate in scientific discourse. As we will see in a later episode in which Tanya and her peers are working without teacher supervision, her display of sense-making can be distinctly different.

3) *Self-contained structure keeps student contributions from arising naturally.* The notion that sharing presentations are often expected to 'stand alone,' unexamined in subsequent discussion, is evident in the following episode from the Riverside class. Erma begins within the rules for presentations– offering a self-contained argument without reference to previous classroom events:

Erma: Okay, I think, that when it's summer in the north, it's winter in the south. But I think that the closer you are to the equator, the warmer it is. No matter whether it's summer or winter. I think that when it's spring in the north, it's fall in the south. Okay? . . .

At this point, Erma provides a conversational hook which will be examined in a later section ("I think that, I don't think that, there, there are like four seasons at once, I think it's either summer or...."). Of interest here is the teacher's reaction when several students grab that hook and attempt conversation. He interrupts

the attempts, inserting a sharp boundary between what should have been a self-contained explanation ("Fine Erma, that's good. You've had your explanation.") and his request for another volunteer ("who else would like– . . . ?"). The effect of conversational restriction is illustrated by events in the Hillsborough class, where the self-contained nature of each group presentation inhibited interruptions from students.

In a parallel example from the Hillsborough class, the teacher curtailed discussion of a question from a group member. The group involved was the one that articulated a theory of the seasons characterized by upward movement of the sun (which produced summer and longer days in the northern hemisphere) alternating with downward movement (producing a northern winter with short days). Ivan evidently had an alternative view which caused him to interrupt his group's presentation to ask a question, a breach of presentation protocol. This naturally arising question was subjugated to the demands that a group presentation present a uniform viewpoint.

Ivan: [Ivan (in group) raises hand] Teacher? <H' can I> know the difference ** * [points to model] * * < example> ?

Teacher: Ivan. . . That's for a group theory. It should be group theory.

As a rule, then, students did not ask relevant questions as they naturally arose in the discourse. Rather, question and answer slots were provided at the end of presentations. The fact that very few students asked questions during these slots may be a telling commentary on the importance of having contributions arise naturally.

4) *Non response to challenges.* During the pure presentations in the Hillsborough class, students who spoke up during the question/answer period largely requested clarification of content or procedure (e.g. "How did you come up with your theory?") rather than posing challenges to the ideas presented. Whereas students were prohibited from interrupting ongoing presentations, the teacher could do so. The teacher also tended to ask clarification questions ("What did you mean by ____?") rather than challenging the validity of statements, the latter being a discourse pattern more typical of theory-building through conversations (Ochs et al, 1992). While clarification questions and questions about the origin of a theory are certainly appropriate within a sense-making conversation, the kinds of questions we found in these presentations were either general and somewhat formulaic or targeted to a particular statement, but in neither case was a specific aspect of the theory challenged.

When students did challenge their classmates' ideas, as sometimes occurred in Riverside despite the established presentation rules, the teacher often halted further conversation. This happened following Erma's presentation (above). On other occasions, the person to whom the challenge was directed apparently felt no obligation to respond– in violation of conversational expectations. For example, in a set of presentations to which we will return in a later section, Gail asked the following question after an elaboration of a theory of seasonal bands by Alison (similar to climate zones):

Gail: but Alison,. does it change ? or just does it—

Gail was inquiring whether seasons would change if Alison's equation of seasons with climate bands were true. When the camera pans back to Alison, she neither acknowledges Gail's question, nor does she answer it. Gail's challenge was very

unusual in the context of these presentations. It can be seen as a conversational move. However, Alison's response is consistent with the notion that presentations are self-contained entities that are not necessarily answerable to the larger community.

Presentations as static discourse

The examples given above demonstrate how presentations ignore relevance and thus impose a static quality on what might otherwise be a dynamic discourse. The variety of potential participants at any change in turns is reduced. In the interest of time, teachers often diverted interruptions, returning to the pre-established presentation format. When a student had the floor he or she was not to be interrupted until an entire monologue had been presented. Without the given/new regulation of conversation, themes failed to develop across turns. In addition, relevant opportunities to challenge assumptions, agree with statements, or add corroborating evidence were lost. As a result, students spent little time comparing and contrasting their various theories. Although the teacher asked questions encouraging comparison, the class often answered with simple unelaborated *no*'s:

Teacher: . . .all right. I would like the rest of the groups that are in their seats to tell me is that theory (the Dudette's theory) the same theory as the Hooks? Hooks, why don't you tell me.

Hooks: No. (in response to comparison question)

Teacher: No, what's different about their theory?

Hooks Boy: (from seat in classroom) the sun (cough) *, ********.

Teacher: all right. The movement of the sun certainly is different. . . .

Later in the lesson, after the third group presented (DQ's group), the students and teacher did briefly contrast theories, but as the excerpt below shows, the discussion lasted for only one student turn and the comparison briefly summarized the major differences. Just prior to this excerpt, DQ had presented an explanation for changes in day length that involved a sun moving up and down in space. When the sun goes up, it shines more on the northern hemisphere, creating summer and a longer day. Movement down creates winter in the north and a shorter day. This model created the same effect as would a tilted earth and a stationary sun. However, this similarity did not have a chance to surface in the teacher's push to move on to writing the theory on the board.

The teacher offers the class a chance to compare three group presentations:

Teacher: . . . Now, . . all of you have seen the Hooks' theory. All of you have seen the Coolettes' theory. . . I would like to now, get your theory, as to whether this is the same as the Hooks or the Coolettes. Ellie?

Ellie: *** the Coolettes and the Hooks, the sun was, . . here, it was tilting , the earth got tilted, but on– but ** the sun keeps going up and down.

Teacher: Okay, they've got the sun going up and down. With the,.. Coolettes we have the sun going, in/out left and right. And , with the Hooks we have the sun going in, and out.

The softly spoken student comparison unclearly contrasts the major actions presented by each model — the Coolettes and Hooks talked about a tilting earth, while DQ's group described a vertically moving sun. Although the teacher clarifies Ellie's contrast, adding her own emphasis on the essential movement of the sun, exploration of the world that would result from each model does not take place. An opportunity for conversation is not taken.

Clearly, engaging in in-depth comparisons is not the major point of presentations as a classroom language activity. In the presentations described, every group (or individual) had an equal opportunity to present their ideas. We sense that the highly structured presentation format in the Hillsborough class may have been designed to teach the students *how* to do presentations, while the Riverside presentations allowed the teachers and researchers to assess each student's knowledge of seasons theory. But what happens when students begin addressing one another and the teacher in conversations? Will students begin to compare and contrast ideas in the effort to choose 'best' explanations? And will students begin to substantiate their ideas with data that allows one theory to emerge as the best explanation of data? Before we can answer these questions, we must first establish that our data contains the features of relevance found in conversations.

Conversation as Supportive of Sense-making

As more features of conversational relevance are preserved, the opportunity for learning or changing one's opinion may increase. Marking *given* and *new* information may help students to compare and contrast their views with those of others. When comments are spurred by what has gone before, ideas may be evaluated and challenged. With this comes the possibility for real epistemological change. Challenges may focus on an inconsistency in a model, a conflict between two models, or an inconsistency between a model and known facts. Such challenges may focus attention on the scientific model or the fact *per se* and thereby behaviorally model, for the participants and listeners a differentiation of the model and data. In presenting evidence consistent with these proposals, we will first establish that conversation can occur in classroom science lessons and second that it is associated with a change or movement of ideas. While of central interest to our research program, it is beyond the scope of the current study to establish that the modeling of differentiation in conversation leads to its later use by students.

The two Hillsborough teachers conducted a discussion with their combined classes regarding what students thought causes the seasons. In this informal lesson, children were seated in a large circle. After some initial discussion, one teacher suggested that the students pantomime the earth/sun relationship associated with their idea of seasonal change. One boy, seated in the middle, represented the sun while other students used their bodies to model the earth's orientation to and movement around the sun. Several students proposed versions of the facing theory, in which winter is placed on the side of the globe away from the sun, summer on the side facing the sun, and spring and fall on the twilight areas between the back and front. Students who proposed the facing

theory accounted for variations in warmth, warmer when facing the sun and colder when turned away, but they failed to acknowledge that these temperature fluctuations occurred with the passage of day and night. Facing could not also account for the seasons.

Here is how two children articulated their versions of the facing theory— Caitlin accounts only for seasons, while Paul accounts for both day and night and the seasons using the same mechanism without realizing it:

Caitlin: when the world turns, <New England> always facing the sun . So, when its not facing the sun it causes winter , so you don't have much light or , much warmth , and, in the summer , it's facing the sun , so its warm , and we have a lot of light .

[and just a few turns later]

Paul: hum (sigh) * * face the moon , and then night time is when it's not facing the sun.

Teacher: OK . does the day and night time have anything to do with the changing of the seasons?

Paul: no.,

Teacher: I just wonder. . . . what do you think causes the changing of the seasons? Paul?

Paul: seasons? , uh , the world revolves around the sun just * * * (big breath) uh, when we faci– , when we're facing the su –. . .

Teacher: relax. you're doing just fine.

Paul: and when we're facing the sun,...we get a lot of heat in the and * not we get a lot of cold . *****....

In the pantomimed development of the facing theory that followed, students at first did not seem troubled by the apparent contradiction that the earth's spin accounted for both day and night and the seasons. One student however did recognize the problems posed by the facing theory. Chrystal raised her hand, thus *selecting her own turn*, and offered the following challenge to the ideas of her peers. She began her challenge somewhat inarticulately– stating her objection to the facing theory but getting tangled in an attempt to explain the seasons. This inarticulateness attests to the spontaneous, unrehearsed nature of her contribution, which probably means it arose as a *natural response* to the conversation that had gone before. Notice also that she summarizes[1] the prevailing theory, marking it as *given* in the preface to her challenge:

Chrystal: **...I don't think that when it's dark that it all of a sudden turns winter, cause that's when it gets night out and when, it spins around...see, it takes a day for it to spin around, but it takes a year for it to go around the sun.** So, when it's, on a certain part of the sun, then it, uhm, well, see ...um, it's tilted and it's it's spinning around, and it's going from day...and stuff like that. And it's going around the sun. But it takes a year for the sun, so, when it's in one part of the sun, it's one season and then the next, is the other season, because when it's, when it's, when one–

The teacher interrupts and asks her to shift from simply talking, to talking while pantomiming her idea. She then restates Chrystal's argument, checking to see if her version accurately reflects Chrystal's.

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[1] Bold marks Chrystal's summary and her challenge to the prevailing theory.

Teacher: All right. You're making g—, no I'm was g— I was just going to stop you because, you do make a lot of sense, and everyone has who has spoken today and I want you to show us, and I'm going to ask you to do something. You now said, and correct me if I'm wrong, **you're telling us that it is not the spinning around that causes the seasons.** Isn't that what you're hearing folks, her saying? **She's saying that causes day and night. She says, correct me if I'm wrong, Chrystal that, it's the going around the sun, the actual going around the sun, that causes the seasons.** Could you show me where winter would be?

The teacher, by restating Chrystal's new contribution, clarifies it, making it more accessible to other students in the class.

Chrystal next does two things that provide conversational hooks for sense-making. First, she establishes *given/new* information, although part of her 'given' has been rhetorically fabricated: "everybody else says" that the direction faced by the earth determines day and night (her rhetorical fabrication, since none of her classmates actually said this). By attributing to 'everybody else' her assertion that facing and spin creates day and night, she has rhetorically established this as a "given" and continues her argument from there.

Secondly, Chrystal again places her remarks in opposition to the prevailing classroom facing theory, this time illustrating with body motions. Her pantomime directly *responds to the teacher's challenge* that Chrystal clarify her ideas by "showing us." In so doing, she continues to uphold conversational relevance:

Chrystal: *[standing and using her body to represent the earth]* I don't really, I don't know exactly, but you see, like, um, everybody else is saying that, when

it's facing this way [faces her body toward the 'sun'], that it's daytime and this way [faces away from the 'sun'] that it it's night time, and that's what it really is. But then they're also saying that this [toward sun] is summer and that this [away from sun] is winter, but it's not because it, it, it takes, to go around the sun, the whole year, and that means it...

Teacher: All right, okay. I, all right Chrystal. But, you could— can you tell me when winter is? What does this tilt have to do with that?

Chrystal: *(unintelligible response)*

Teacher: Okay. Kelly, you're next, then Mr. Martin and Mike, you're after Mr. Martin.

Chrystal claims that the class is erroneously explaining both seasons and day/night by the single facing mechanism and substantially alters the shape of subsequent arguments. The class has begun making sense of one piece of the puzzle.

If presentation structure, with its value on equality of turns had been in force during this lesson, Chrystal's challenge would never have been aired. This was her second turn. The full extent of the potential loss becomes apparent when we examine the effect of her challenge. Chrystal raises the issue of what the classroom models are trying to explain. The turning of the earth explains day and night, it cannot also explain the seasons, she argues. She does not actually present her own alternative theory. She is only commenting on what it is that can be explained by the models the other students are advocating. The teacher does not comment on Chrystal's challenge but in subsequent contributions, the

facing theory no longer appears. In its place the *distance theory,* which is not inconsistent with Chrystal's challenge, becomes dominant.[2]

The theory that takes over in the class discussion is the distance theory as described by Jake in the excerpt below. He describes the earth moving in an elliptical orbit around the sun. In his view, the ellipse accounts for the variation in distance from summer to winter:

Jake: the earth goes **** when it's spinning around it gets farther away from the sun and it gets colder. It goes around and in the summer it's like *****

Teacher: It goes farther away from the sun in winter and closer in the summer. All right. Does tilt have anything to do with it, that Ivan is talking about?

Jake: I don't think so.

The previous examples from the Hillsborough class show how preservation of conversational relevance within the structure of classroom lessons allows for movement and change in the student theories that prevail in the discussion. Chrystal's challenge to the prevailing facing theory, which articulated a problem with the theory itself, rather than just asserting an opposing view, opened the way for alternative theories. While Jake's theory is stated without reference to earlier proposals, it, and all other subsequent proposals, are consistent with Chrystal's critique.

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[2] In student *distance theories,* winter occurs when the sun is further from the earth. Variations in distance occur either through movement of the sun itself, through the earth's ellipitcal path around the sun, or through hemispheric tilt away from the sun which, at the scale of the classroom models, increases its distance from the sun.

In the previous example of classroom conversation, the teacher played an important role in managing the discussion, highlighting the relevance of turns to previous turns and summarizing points. Our data also contains an example of a conversation that is regulated by the students themselves, without teacher mediation. The adult participant, Bethany, is listening to but not moderating the conversation. The students regulate their own turns, freely interrupting or standing up and going to the board to comment on or respond to the challenges of others. When Tanya demonstrates the relationship between earth and sun, she fends off a classmate's attempt to gain the floor, holding it without teacher intervention:

Odette: Wait. At night at night it turns like this

Odette: At night it turns and um.=

Tanya: Wait, wait, wait–

Tanya: I'm not done yet. Um. And uh at the night like when the night its kinda colder and stuff 'cuz it's getting dark– . .

Odette: Right.

Students *respond to challenges*, often admitting error by agreeing with the challenge. For example, Odette explained her facing theory: "when it turns (rotates globe on it's axis) all of the sun is shining on it. . . and then it comes to summer." Tanya objected to Odette's articulation of the facing theory, claiming instead that "turning" only accounts for day and night, as seen in the excerpt above. Following some other discussion, Odette goes to the blackboard and draws a diagram with the earth in the center and the moon and sun on either

side. She explains that as the earth turns you move from the sun to the moon (day to night), essentially agreeing with Tanya's earlier point.

These students use the blackboard in an interesting way to set *new* information apart from given. For example, after discussions and drawings representing the day/night issue, Tanya takes a turn at the board, drawing a diagram of the earth with the Arctic circles and equator carefully labeled COLD and HOT. She has highlighted her new information by labeling the diagram much in the way teachers highlight new information. But unlike the typical lesson, Odette feels free to approach the 'sacred space' surrounding the blackboard to clarify Tanya's diagram. Tanya then redraws the diagram.

Tanya: I know, 'cept. Oh, yeah yeah yeah. I did something wrong. I did something wrong, sorry. [erases diagram and draws another earth with equator] . . .

Most important in these examples is the way in which students freely modify their views. In the next piece we see the role of conversation in leading to the elaboration of the model being proposed. Tanya is at the blackboard:

Tanya: OK. ****** Wait this is like summer and spring. [writes the labels 'summer' in southern hemisphere and 'spring' in northern hemisphere]** See? like **[draws arrow pointing to the area around the northern tropics]** When– this is like the globe , ok. [Goes to globe, out of view of camera] Around here . . .

Bethany: Yeah.

Tanya: . . .this give you spring,.

Bethany: Yeah.

Tanya: around there is summer. OK. **The sun is pointing here. . . [draws arrow pointing to southern hemisphere]** . . .

Tanya is using the arrow of the sun pointing toward the southern hemisphere to indicate the cause of summer. At this point Datara asks "where is wintertime?" a question reminiscent of the quadrant theory in which all the seasons are represented on the globe at any time.

Datara: But where is wintertime.

Tanya: Summer. The sun is —

Tanya: [to Datara] There is only two: season at once. [turns toward Datara gesturing with great emphasis]

C?: No there's one season at once.

Odette: (laughs) Just let her talk to **.

Tanya: and, OK

Elsa: she needs to talk.[goes to board]

Tanya: The sun is like shining a little bit here.

Bethany: OK. OK alright.

Tanya: See? And — and it's change it change this becomes like winter and this becomes . . .what i'?

Child: fall

Tanya: fall.

Bethany: OK.

Tanya: That's it. [puts chalk down] I have a seat.

Tanya's reply to Datara is emphatic. Tanya goes on to talk about the alternation of seasons which accounts for the existence of only two seasons. In the course of this presentation by Tanya, both Odette and Datara make clarifications and raise questions in a conversational, collaborative manner.

It is interesting to consider what it is that invites Odette's and Datara's contributions. These contributions seem to go beyond just getting the presentation right. In this case, the fact that Tanya put the theory on the board opened it up to discussion with Odette. Datara's question, asked quite sincerely, may easily have been a simple comment on the impropriety of the theory as a presentation (facing and quadrant theory presentations always show where all four seasons are located). Tanya's response, however, goes beyond just the correctness of the way-things-should-be-represented to emphasize the point that the seasons alternate. Her introduction of the alternation mechanism as a way of accounting for only two seasons existing at once suggests that she considers this fact to be the data to which her theory is responsible (a fact that their teacher had emphasized in an earlier lesson). It appears that because Tanya has a mechanism in mind, she has a basis for not just disagreeing with Datara but for emphatically denying her presupposition and for going on to complete the model she was diagramming. In any case, Datara's spontaneous question is the occasion for clarification and extension of Tanya's theory. The interaction as a whole demonstrates considerable strengths in scientific expression in several modalities, in co-construction of meaning and in an effort toward sense-making.

Classroom conversations of this sort are not common. But the examples from our data illustrate that the more open structure of conversation supports students as they compare and contrast the theories aired in the class. Two very different views may be juxtaposed in time, and rather than getting lost in the requirements of a forward marching presentation format, students are free to revisit the ill-fitting puzzle pieces, and raise their objections without worrying about having a fully formed theory to fill the void. Their contribution can be picked up in turn by another student. Thus change can occur as a result of the challenges that arise when students self-select. We see Chrystal's and Tanya's challenges having an effect on later presentations in that the facing theory was effectively eliminated. Perhaps more important than a change in belief about the seasons (which in any case was toward the distance misconception) was the display of a conversation in which some students brought up challenges and other students presented theories that attempted to address those challenges.

Conversational Presentations

We have argued above how 'pure' presentations reduce relevance in discourse, and how conversational relevance can promote movement in ideas. However, presentations and conversations are often found in hybrid forms in the classroom. Conversations were rarely the true peer to peer conversations described by Cazden (1988) and Lemke (1990). Conversely, presentations sometimes became conversational. We will next search out the elements in these hybrid forms that provide conversational hooks, allowing participants to build a lattice upon which ideas may be aired, developed, challenged, and revised.

Students in our Riverside class sometimes ignored the restrictions of the presentation format, placing their remarks instead within a larger frame of

interaction that spanned several presentations. They volunteered to go next when they heard something provocative. They challenged a classmate's claims in violation of a 'rule' restricting comments or questions. By referring to the comments of previous presenters or implicitly developing a common theme, presentations began to take on many of the features of conversations.

Contrasting one's own contribution with the ideas of others is one way to draw others into a conversation. Erma from the Riverside class, inserts contrast into her presentation. In arguing that only two seasons exist at once, she refers to a prior student's theory. Erma contrasts her position with this earlier assertion that the seasons occupy four different spots on the globe at once (quadrant theory):

Erma: Okay, I think, that when it's summer in the north, it's winter in the south. But I think that the closer you are to the equator, the warmer it is. No matter whether it's summer or winter. I think that when it's spring in the north, it's fall in the south. Okay? **I think that, I don't think that, there, there are like four seasons at once, I think it's either summer or...*[gestures to northern hemisphere]*.**

Student: That's what I'd like, to say.

Carielle: But I'm saying that...*[several students speak at once]*

Teacher: Shhh. Shhh. That was Erma's explanation. Fine Erma, that's good. You've had your explanation. Now. I think, do you need to, who else would like–...? [students raise their hands]

Erma's contrast, "I think that, I don't think that, there, there are like four seasons at once," offers a conversational hook to others in the class. She accompanies her bid for relevance with dysfluent stops, starts, and repeated words. It appears

that within the presentation structure set up by the teacher, crossing the boundary between sharing presentations and conversation was not easy.

Erma's tentative bid for relevance, which effectively placed her idea within the larger classroom discourse, produced expected results. Several students made bids to respond. A conversation never developed, however, for the teacher carefully maintained the integrity of the "sharing" presentation structure, the goal of which was to give everyone a chance to perform.

Other conversation-like devices were also apparent during this lesson. A sequence of four presentations that followed Erma's illustrates conversational qualities mixed with presentations. Mallory, Mitchell, Alison, and Max present in turn—each subsequent presentation implicitly and explicitly building on the others. In the process, they develop the following related themes:

1) Climates and seasons encircle the globe at a given latitude.

2) The hemispheres are symmetrical with respect to climate bands.

3) An entire hemisphere has only one season at once.

4) There are only two seasons at once.

Mallory, the first girl in the sequence, reluctantly presents. She begins by introducing a generalization about the earth's climate bands— It's always warmer on the equator and cold at the two poles. Mallory then gets stuck and halts her presentation. After a reminder from the teacher to draw upon what she's learned during previous lessons she finally rephrases the quadrant model proposed earlier by Maurice – laying four seasons onto the globe in quadrants:

Mallory: Well I think it's always warmer on the equator 'cause it's always ***, I don't know. It's always near the sun.

Teacher: yeah.

Mallory: and it, always cold at the two poles. And, I don't know, well (four second pause) I don't know, I s–. **

Teacher: **** from ye–, what you've learned from data you've taken, what you've done,and what you've talked about, and what you've modelled,

Mallory: u:m , right here , the sun's up there, okay. And this is, like um , summer , and here's spring , and , um , fall , (quietly) and winter down here,

Teacher: the Maurice model, basically.

Mallory: What ?

Teacher: Basically that's the Maurice model.

Mallory: I guess.

At this point Mallory and her teacher's co-constructed performance departs from the pure presentation format and admits some conversational relevance— the teacher suggests that her 'theory' is similar to Maurice's. Mallory, however, contributes to the unfolding conversation by introducing data neglected by earlier theories– it's always warm at the equator and cold at the poles. This theme is further developed in subsequent discourse.

Mitchell begins his turn by establishing a conversational link. He agrees with Maurice. Apparently, he agrees only that there are four seasons at once, for he

subsequently lays four seasons onto the globe in bands rather than quadrants as Maurice had done:

Mitchell: I have , two, *[while walking toward globe]* okay, I agree with Maurice. And I also think that um , that when it's , w' if it's spring up here [gesturally indicates a band around the globe], then it's , um , um wait . . ., okay it's, it's fall up here [continues to gesture 'bands' for each season], then it's, winter down here, and it's, summer over here and spring down here.

Teacher: okay you have bands around the earth for the uh seasons.

Mitchell also explicitly marks his ideas as different from Maurice's in some way ("and I also think that . . ."), but the actual difference is expressed through gesture. Although he never says some equivalent of 'I agree there are four seasons, but I think they are bands, not quadrants.' his more subtle verbal and gestural marking of new information succeeded in communicating his idea to the teacher, who labeled the idea ("bands"), making it accessible to other students. With his notion of bands, Mitchell introduces the possibility that a given latitude has the same season.

Alison volunteers and is called on next, though Max is quite anxious for a turn. He has actively been trying to self-select since hearing a return to the quadrant theory following Erma's assertion that only two seasons occur at once.

Teacher: *(very softly)* What do you think?

[Max madly waves hand in the air.]

Alison: Uhm , I agree with Mallory.

Teacher: Can you show me why ? Why do you <agree with Mallory>?

Alison then continues her turn in response to the teacher's question, "Why do you <agree with Mallory?>?" She repeats information given by Mallory regarding the existence of cold poles and a warm equator, but in keeping with a self-contained presentation, does not further cite her source. She merely repeats it as a statement of the facts, the *way things are*.:

Alison: *(softly)* Because it's cold here and here *[motions toward poles]* and then in the middle, as it gets—as it comes to the middle it gets warm. And so here *[motions to band around equator]* along here, would be summer, and then here it's spring *[motions to symmetrical bands on either side of the equator]* here . . . fall, and winter. *[continues with symmetrical bands]*

Teacher: Well that's similar to the band model of Mitchell's * * *, *****,

Alison has combined two thematic strands into a more coherent whole–the notion of temperature gradient (incompletely introduced by Mallory) and the band model proposed by Mitchell. By associating summer with the equator, winter with each pole and fall/spring on the gradient in between, she integrates previous efforts to explain temperature gradients with the notion of continuous seasonal bands.

A fascinating progression has taken place from Mallory to Alison. Mallory introduces data that had been neglected by earlier quadrant theories: it's cold at the poles and always warm at the equator. She has a difficult time integrating this new data into her theory, however, and falls back on the quadrant model of the seasons. Mitchell's band theory introduces another new concept, that there is no "back side" to a season. Rather, seasons exist in continuous bands that

encircle the globe. But he is unable to take temperature into account in assigning seasons to the four bands. The demonstration given by Alison neatly combines the previous efforts toward explanation of temperature gradients with the continuity of a season within a hemisphere. In addition, she non-verbally informs us that she has an understanding of yet another piece of data, that the hemispheres are symmetrical with respect to temperature.

Max finally gets his turn and this is what he says.

Max: When i— it's— *(sing-song intonation)* it's always warm near the equator. And, when it's, uh... winter, up here, *[motions to northern hemisphere]* it's summer down here. *[motions to southern hemisphere]* And there's . . . *(3 sec pause, hand on chin)*

(quickly) spring up here and fall down here. *[motions to same spots as before, speaking quickly]*

(very softly) I agree with Erma.

(ten-second pause without teacher remarks directed at Max, who stands spinning globe.)

Max's performance does not work well, stripped as it is of conversational relevance. He fails to make explicit a seeming change in time that occurs while his hand is on his chin (from winter to spring in the north and summer to fall in the south). The link he draws with previous discourse ("I agree with Erma") is offered almost as an afterthought, and even then so softly that the student's name was mis-transcribed across several revisions of the transcript.

But the thematic movement in this conversation of sorts has progressed to a logical conclusion. Following Alison's development of two symmetrical hemispheres, Max asserts an alternation in which there are only two seasons present at any given time. This alternation is a key point that is missing from the band theories since it moves toward an explanation of the changing seasons.

While this episode was a sequence of presentations, important elements of conversation entered in. Max's hand raise indicates the point at which he felt he had a contribution to make, i.e., right after a four season theory had been presented. The fact that students self-selected during this sequence resulted in the building of a picture of symmetrical bands. Each presentation adds something new although the relevance is not always marked.

Language Activity and Epistemology

We have tried to characterize two dimensions that are important for classroom discussions of science. The first dimension has to do with the goal of science instruction: that students should master a scientific epistemology that requires a shift from the common-sense description of the way things are to a differentiation of theory and evidence. On the second dimension is two ways of organizing science discourse in the classroom once you move away from the typical teacher-led lesson. The hypothesis that is guiding our examination of science discussions is that these dimensions are not entirely independent.

Presentations as Support for the Way-things-are

Features of the presentation mode appear well designed for the way-things-are approach to theorizing. It is clear that way-things-are theories were left unchallenged in the presentation mode. It appears that the presentation mode

was designed, at least in part, to give all students a turn and to deal with the unevenness of participation that could occur in the conversation mode. The teachers' apparent preference for presentations may also be related to an approach to theorizing that values the students' contributions as all equally good or interesting.

The presentation format has several strikes against it as a context for developing scientific sense-making in the classroom. By disallowing conversational relevance, opportunities to change or develop new ideas among the students is reduced. More importantly, the unchallenged, sometimes rehearsed presentation seems to invite simple statements of the way-things-are. The NKAMS (New Kids at McKinley School) consisting of Jessica and Mia (the third member was missing) was typical of a well practiced presentation that not only is unresponsive to previous presentations but is not actually responsive to the data that it purports to address. The dissociation of the data and model goes unchallenged in this context which favors the correct presentation of the accepted theory.

Teacher: So we need NKAMS t'be next then.

Jessica: Uh we think that like from, September first to the winter solstice the days keep getting uh,

Mia: shorter,

Jessica: shorter,

Mia: And then from the winter solstice til, March,

Jessica: February 14 today, the days are getting longer.

Teacher: OK, that's your pattern, now why do you think that happens Jessica? Let's do why you think that happens before you write it.

Jessica: Uhm, well because for the winter solstice it's the shortest day of the year, so from the winter solstice the days keep getting longer, and like, cause like the sun, well cause like you go like this, right, this is summer, when like, cause we're facing the earth and then it turns and then this is spring, and when the sun's away from us, this is, *[Jessica carries the globe walking around Mia who is holding the sun. She correctly maintains the tilt of the axis as she moves around.]*

Mia: Winter...

Jessica: Winter for us but it's summer for here, *[indicating the southern hemisphere],*

Teacher: uh huh,

Jessica: and then it turns like this and it's, fall here but its spring here, then, it turns around, this is summer and this is winter *[continues walking around Mia]*

The teacher says "lets do why you think that happens" and Jessica first repeats a version of the data. Immediately, however, Jessica shifts gears and starts to "run" a model: "cause like you go like this, right, this is summer." She then walks through a pattern showing where the seasons fall in the orbit of the earth around the sun.

In fact, Jessica fails to explain how the relative positions of the earth and sun might affect day length or even specifically how it might cause the seasons. The physical model she enacts is the accepted correct model, but there is no

indication that this model, as she presents it, serves as an explanation for anything. In this classroom, students became practiced at modeling seasonal change but not all students, at this point in the year, used models as explanatory theories.

Explanatory theories are not, of course, prevented by the presentation format. Here is an example of a student who appears to be coordinating data and her model within a presentation format. Gail, a fifth grader in the Riverside school, presented an explanation for the change of seasons that involves a careful placing of features of the model that are important for the demonstration and an explicit statement of causality.

Teacher: You would like to make an explanation ?

Gail: Yeah. Well, I'll say that the sun is over here. [Outstretched left hand representing the sun, right hand touching globe.]

Teacher: Yeah .

Gail: And well, if it's shining like, wait I'm gonna have the axis pointing over here the whole time. *[Turns globe with axis pointing away from sun, her left hand.]* The sun's over here, okay? *[Gail continues to hold her left hand out, representing the sun, throughout this portion of her demonstration .]* Now right now, it's, it would be shining *(2 sec. pause)*, let's see. Over, right, about, straight on the equator. *[Traces a line with her right hand from the sun (left hand) to globe, hitting just below equator.]* No, right about here. *[Hand taps globe just below equator then repeats her tracing of the line from the sun to the globe.]* More on, the, southern hemisphere. Shining directly about over, somewhere over here. So, w—, 'cause it's like, winter, or, and, up,

it's winter in the north. *[At "up" places hand on northern hemisphere on the side of the globe facing the sun.]* And then, as it gets to be closer to spring *[touches equator]*, as it moves around, *[traces a line of orbit counterclockwise]* Well, move it *(to Erma)*. But, okay Erma. But, it would, the sun would be more directly over the equator in spring. *[Erma carries globe 1/4 revolution around Gail.]*

Student: *(Very softly)* winter.

Gail: Over the equator in spring, and then over here. *[Gail takes globe, places it on a desk 180 degrees from its starting place. The tilt of the axis remains in its original orientation.]* When it's over this way, it would be summer in the north. *[Touches northern hemisphere.]* But then it's still directly over here. *[Indefinite gesture at equator.]* So, as it, the closer you get to where it's directly overhead, the warmer it is.

Gail's observation that "The closer you get to where it's directly overhead, the warmer it is" is an indication of the causal, explanatory nature of the model she is constructing. She is referring to warmth not just summer. Warmth, not summer, is the data that results from the direct sun. It is a general statement that predicts a relationship between the cause and the event. We also notice Gail's careful placement of the globe, sighting the angle of the sun and maintaining the orientation of the axis, suggesting that these features have a purpose in the theory beyond the display of "the way things are." Gail also shows a hesitancy in organizing all these features indicating that this is not a rote performance.

We suspect that, if it were understood at all, Gail's presentation could be assimilated by many of the other students as a statement of her opinion of the way-things-are. That is, for students who use the way-things-are epistemology,

the more complex sense-making process may not be interpreted as such and may provide no information that would lead them to adopt a different epistemology. There was no challenge or follow up to this presentation which could have independently highlighted for other students particulars of the data being explained or features of the model used to explain them. A function of explicit follow up or challenge may be to make salient the very differentiation that is the core of scientific sense-making.

Conversational Support of Sense-making

While we recognize that students such as Gail (or scientists at a conference) may engage in sense-making in the context of a presentation, it is less likely that the listeners will learn about the process of sense-making itself from merely witnessing the presentation of its end-product. The sense-making process includes sifting through observations for evidence, building theories, revising based on new evidence, dealing with challenges and testing through counter-examples. A challenge by another student or the teacher can begin to display the differentiation of model and data or treat the model as an analyzable artifact.

We suspect that an effort toward sense-making might tend to turn presentations into conversations. The differentiation of data and model provides the basis for argument and challenge. Without the differentiation, any theory is as good as any other since there is no basis for showing that one fails to account for known data or even that one is more elegant than another. The explanatory model provides the decomposition into something that can be held in common and something that is different between two "theories." That is, the notion of the model as an artifact distinct from the phenomena provides the hooks for critique. While sense-making may favor a conversation, the main issue is whether a

conversation is the more appropriate context for constructing scientific sense-making.

The conversations we observed in the fifth and sixth grade classrooms may be a long way still from our ideal of a scientific sense-making conversation. For the most part, students were simply presenting their theories as the way-things-are. The fact that we found both a mixture of epistemologies displayed and movement from in the conversation from one theory to another is evidence that the relevance allowed in the conversational format may open the possibility of a growth in student's epistemology as well as in their beliefs about the world.

The Rhetoric of Science

Linking their point to what a previous speaker said, presenting an argument so as to mark given and new information, and articulating relationships between evidence and theory might all be considered part of a rhetoric of science that students must acquire. This is quite different from sounding scientific by using appropriate terminology and enunciating accepted theories. But sounding scientific and making clear and fluent presentations may have advantages in being readily understandable and being recognized as "science talk" by both the teacher and other students. Sounding scientific may have advantages in the presentation mode as well as in conversation. We are concerned that classroom conversation, in particular, may tend to be dominated by the students who initially sound scientific. Students who are unsure of their English language skills for example, may be hesitant to contribute to the conversation. But even students for whom English is the first language may have ways of talking science that sound less scientific to the teacher and other students. In the more free flowing

conversation requiring self selection, their contributions may be ignored or misinterpreted if made at all.

We hesitate to conclude that presentations have advantages for such students even though the turn selection mechanism guarantees them an uninterrupted time slot for their turn. Max's presentation in the conversational presentations lacked the rhetoric that would have highlighted the importance of his contribution to the ongoing conversation. But the context was not constructed as a collaboration to which contributions were being made (even though he raised his hand specifically to volunteer one). It is possible that Max could have marshaled rhetorical skills more effectively if a conversational task had been supported.

Tanya's contribution to a conversation as opposed to her performance during the presentation session is suggestive. For Tanya, who speaks English with a Haitian accent, the presentation session was interpreted much as it was intended by the teacher: an opportunity for each individual student to take the stage and say what they knew about the seasons. After much prompting, her performance was an imitation of what she had heard other students say. The observer's impression was of a very shy girl who is unsure of herself and speaks reluctantly.

The researchers had been impressed with the lack of participation by the minority group students especially a group of five girls and late in the year conspired to create a context in which they might feel more comfortable speaking up. A very unusual classroom event was constructed as part of the drama component of the research project, a portion of which was reported earlier in this paper. The drama lessons were lead by Robert Colby a drama professor at Emerson College and Bethany Clay a drama specialist from Lexington Schools.

In this case they divided the class into four homogeneous groups and four adult "actors" led the groups in a dramatic scene modified to match what the adults thought might be the personal characteristics of the different groups. The actor presented him or herself as an aspiring TV weather person preparing for an audition required before graduating from weather school. The students' role was to help this person prepare for the audition which included an explanation of why spring occurs. Working with the group of minority girls, Bethany Clay presented herself as insecure and nervous, especially with respect to the science content which she was sure all the other weather people, her competition in the audition, had down cold.

Elements of students' knowledge of presentations came into play here as they attempted to shore up Bethany's confidence and make suggestions concerning not talking too fast, not looking nervous, and not referring noticeably to her notes. We see evidence that the girls are drawn into the context in their sound advice:

"Slow down when you are talking and don't panic.";

"Don't shake your hand when you're explaining, don't go [demonstrates using the globe]";

"Keep talking and stay cool when you make a mistake. Keep going, cause otherwise you're going to run out of time."

This provides more evidence of the students' understanding of the proper format for presentations. Their understanding goes beyond a knowledge of school presentations however, to include the appropriate contexts for a wide range of discourses, and a keen awareness of the appropriate discourse for each context. For example, Odette sizes up the required duties of a TV weather person and

concludes: "You're not gonna say why it turns spring on TV. You're just gonna say . . ." She has appropriately determined that weather people do not go into long discourses about 'why it turns spring.' She agrees to continue coaching on the spring question only after Bethany makes it clear she will have to know and present this for her audition tape, "or they won't graduate me." Resituated in the context of a school activity, Odette is willing to engage in school discourse. The coaching session therefore moves on to a conversation about why spring happens which is intermixed with demonstrations of how it should be presented.

We find in this context that Tanya raised the same issue that Chrystal and Gail had raised with respect to the facing theory and that an extended discussion at the black board ensues in which Tanya and Odette attempt to clarify the issues, with Tanya insisting that change in "weather" has to take the equator into consideration. The "earth moving" below refers to the earth's spin, and by saying "is like the hour," Tanya links that spin with changes in time of day.

Tanya: . Well the thing the earth is moving only is like the hour. Of uh time of day those things, but it does –

Tanya: it does not tell you about the weather, but turn it around ** only like um ** the– only the equator could tell you that.

Although Tanya, whose second language is English, does not use the school rhetoric and science-talk vocabulary that would have made her contribution clear in any context, she is clearly making the same argument that was made more 'eloquently' by native English students who come from home cultures that support the language of school. She says that day and night, and the seasons are accounted for by two separate mechanisms.

Tanya's eager performance in the weather audition, in contrast to her reluctant performance in the presentation task, shows that given an appropriate motivational frame, she was able to think on her feet and make her point in relation to other contributions. While her English grammar was not perfect, the point came across in diagrams, language and gestures. The weather audition was contrived to elicit the students' participation and was not representative of the everyday classroom. For one thing, the five minority group girls were not competing for the floor with others in the class. For another, Bethany constructed a very non threatening situation in which they were put in the role of expert advisors. But it is clear that, given acceptance of a collaborative enterprise, Tanya and the others can engage in scientific conversations. Where the conversation has an accepted collaborative purpose, they are able to marshal the rhetorical skills that are not available in the presentations.

Our task, however, is to develop a scientific epistemology not just to marshal or develop rhetorical skills. But if conversation is an important context for developing sense-making and if a level of rhetorical and sense-making skill are needed in order to engage in the conversation in the first place, there is certainly a bootstrapping problem that we must address. We obviously cannot assume that students understand the sense-making task initially. It remains to be seen whether we can reliably create contexts in which sense-making can be practiced before it is entirely mastered.

Conversation as a Locus of Learning

This paper has attempted to identify some relevant dimensions to be considered in research that attempts to improve school science instruction. A fundamental point is a definition of what our goals are in terms of a socially constituted

function of explanation that we are calling scientific sense-making. The shift to scientific sense-making is not a cognitive change in the individual's representation of the world. The shift involves the student's appropriation of a way of talking that uses a differentiation of theory and evidence and the use of models and data as artifacts distinct from the target phenomena.

Our data do not include evidence of students learning better in one mode of discourse rather than the other. We have tried to demonstrate only that the students' "theories" are elaborated and developed in conversation. From this it is, at least, a reasonable conjecture that the differentiation of theory and evidence can be constructed in a conversation. But to suggest that conversation is a locus for the construction of a scientific epistemology presents us with a paradox. How can students engage in a "sense-making conversation" before having learned the scientific epistemology on which it is based? We conclude by addressing the question: is it possible to engage students in a sense-making conversation in order to bring them into sense-making as a way of doing science? Can the conversation be bootstrapped?

Bootstrapping the Sense-Making Conversation

The classroom conversation is bound to be messier and more challenging for the teacher than a sequence of neatly distinguished presentations. We saw, for example, that often when students were intent on working through an idea on the spot, they were quite disfluent and often barely interpretable. We find a more difficult puzzle however in the apparently necessary assumption that students are capable of scientific conversations in the classroom. If they have not developed the necessary differentiation of theory and evidence, how can they participate in a conversation that requires it as a condition for learning it?

Some students apparently *do* distinguish between theory and data—at least to the extent of being willing to raise objections to other student's theories on the grounds that the theories fail to accommodate known facts (e.g. Chrystal's challenge to the "facing theory" on the grounds that the rotation of the earth accounts for the alternations of day and night—not the changing seasons). But many others of the contributions were simply statements of the way-things-are. Is it possible for a sense-making conversation to develop when few if any of the participants are viewing the issues from a scientific epistemology?

Drawing on work in the Vygotskian tradition, we believe that a case can be made for the interactive construction of the differentiation of theory and evidence within a conversation composed largely of conflicting statements of the way-things-are. At times we have observed a series of such presentations building on each other, in what becomes a sort of conversation. A model is developed collaboratively. As other participants refer back to the model or its features, it may begin to acquire a status of artifact within the conversation. A statement of the way-things-are may be reconstructed as a differentiated model by the responses of other students or the teacher who are differentiating theory and evidence. That is, when a statement of the way-things-are is critiqued on the basis of its mismatch with evidence or internal inconsistency, when it is treated *as if* it were a differentiated model, it may become such within the conversation. The teacher and the other more advanced students reconstruct the presentation or conversational turn.

If nobody in the conversation is supporting the differentiation of theory and evidence, then it is unlikely to occur in the conversation naturally. A teacher who approaches science as a matter of conveying the correct answer to how things actually are, will certainly prevent the construction of the differentiation on the

classroom discourse. But even where the teacher firmly holds a scientific epistemology, there are many practical impediments to constructing and supporting conversation that involve all the students in the practice of sense-making. For example, the problems of the heterogeneity of schools like the one we worked with in Riverside highlights the issue of constructing goals that all the students can collaborate on.

But at the same time, since it is possible that students can learn from observing conversations among some of the class, it is not clear that it is worth moving to a presentation format just in order to give all children an opportunity to participate. Perhaps the fundamental problem is the development of a classroom culture in which all students feel part of a collaborative enterprise. Presentations allow for the maintenance of the unrelated individual performance and may actually work against that sense of community.

Conversation *is* the Epistemology

We are developing an argument for the importance of classroom conversations. Conversations provide a good match to sense-making because they assume a collaborative goal and relevance of contributions to that goal. The two notions, sense-making and conversation, are not distinct as means and ends. This is both the problem and the opportunity.

The tack we are pursuing is to see the conversation as the construction of sense-making in the class. The differentiation of model and data is a function of the form of the conversation driven by the shared goals. The epistemology is found in the conversation. The construction is thus directly orchestrated by the teacher in interaction with the students and the differentiation thus displayed is available for appropriation by the students. We believe that this point of view on the locus

of constructive activity, in the interaction rather than in the head, will provide the tools we will need to address the bootstrapping problem with which this study confronts us.

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	Language Activity	
Epistemology	**Presentations**	**Conversations**
Way things are	Typical of sharing time	Typical of dinner table conversations
Scientific differentiation of theory/evidence	Typical of some academic conferences	Scientific sense-making conversation

Table 1: Matrix of Language Activities by Epistemologies.

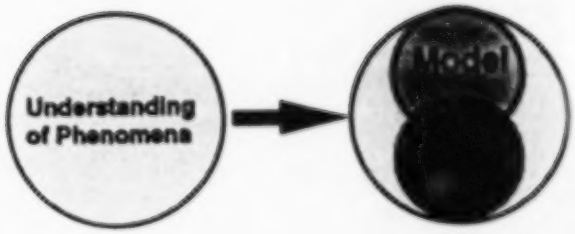

Figure 1: Differentiation of Model and Data in moving from a view of science as describing the way things are.

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